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(54) Multiple frequency bands switchable antenna for portable terminals

(57) A tuneable quad-band radio antenna device (1) for a radio communication terminal, said antenna device comprising a ground substrate (2), a dual-band antenna element comprising a first elongated antenna member (3), a second (4) elongated antenna member, which is shorter than said first member, and a ground connection (11,12) connecting said members to ground. An impedance

switch device (20) is operable to change the impedance of said connection (11,12) for tuning the antenna element, such that in a first impedance setting (Z1,Z3) the antenna element is resonant to a first and a second radio frequency, and in a second impedance setting (Z2,Z4) the antenna element is resonant to a third and a fourth radio frequency which are frequency shifted from said first and second radio frequencies.

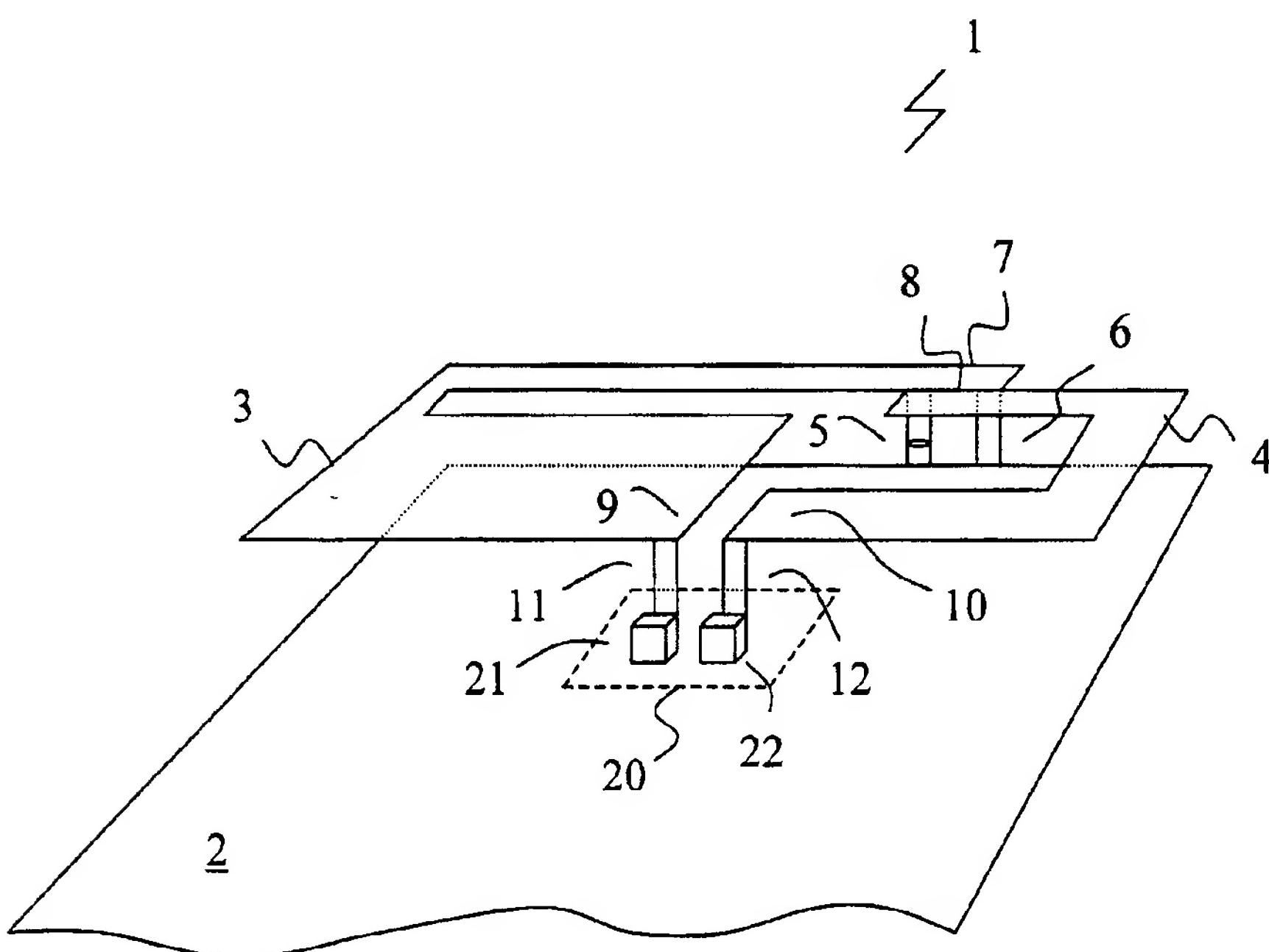


Fig. 1

Description**Field of the invention**

[0001] The present invention relates generally to antennas for radio communication terminals and, in particular, to low-profile antennas devised to be incorporated into portable terminals, and which are capable of operating at different telecommunication frequency bands.

Background

[0002] Since the end of the 2000th century the cellular telephone industry has had enormous development in the world. From the initial analog systems, such as those defined by the standards AMPS (Advanced Mobile Phone System) and NMT (Nordic Mobile Telephone), the development has during recent years been almost exclusively focused on standards for digital solutions for cellular radio network systems, such as D-AMPS (e.g., as specified in EIA/TIA-IS-54-B and IS-136) and GSM (Global System for Mobile Communications). Different digital transmission schemes are used in different systems, e.g. time division multiple access (TDMA) or code division multiple access (CDMA). Currently, the cellular technology is entering the so called 3rd generation, providing several advantages over the former, 2nd generation, digital systems referred to above. Among those advantages an increased bandwidth will be provided, allowing effective communication of more complex data. The 3rd generation of mobile systems have been referred to as the UMTS (Universal Mobile Telephony System) in Europe and CDMA2000 in the USA, and is already implemented in Japan to some extent. Furthermore, it is widely believed that the first generation of Personal Communication Networks (PCNs), employing low cost, pocket-sized, cordless telephones that can be carried comfortably and used to make or receive calls in the home, office, street, car, etc., will be provided by, for example, cellular carriers using the next generation digital cellular system infrastructure.

[0003] One evolution in cellular communication services involves the adoption of additional frequency bands for use in handling mobile communications, e.g., for Personal Communication Services (PCS) services. Taking the U.S. as an example, the Cellular hyperband is assigned two frequency bands (commonly referred to as the A frequency band and the B frequency band) for carrying and controlling communications in the 800 MHz region. The PCS hyperband, on the other hand, is specified in the United States to include six different frequency bands (A, B, C, D, E and F) in the 1900 MHz region. Thus, eight frequency bands are now available in any given service area of the U.S. to facilitate communication services. Certain standards have been approved for the PCS hyperband (e.g., PCS1900 (J-STD-007)), while others have been approved for the Cellular hyperband (e.g., D-AMPS (IS-136)). Other frequency bands in

which these devices will be operating include GPS (operating in the 1.5 GHz range) and UMTS (operating in the 2.0 GHz range). Each one of the frequency bands specified for the Cellular and PCS hyperbands is allo-

5 cated a plurality of traffic channels and at least one access or control channel. The control channel is used to control or supervise the operation of mobile stations by means of information transmitted to and received from the mobile stations. Such information may include incoming call signals, outgoing call signals, page signals, page response signals, location registration signals, voice channel assignments, maintenance instructions, hand-off, and cell selection or reselection instructions as a mobile station travels out of the radio coverage of one cell and into the radio coverage of another cell. The control and voice channels may operate using either analog modulation or digital modulation.

[0004] The signals transmitted by a base station in the downlink over the traffic and control channels are received by mobile or portable terminals, each of which have at least one antenna. Historically, portable terminals have employed a number of different types of antennas to receive and transmit signals over the air interface. For example, monopole antennas mounted perpendicularly to a conducting surface have been found to provide good radiation characteristics, desirable drive point impedances and relatively simple construction. Monopole antennas can be created in various physical forms. For example, rod or whip antennas have frequently been used in conjunction with portable terminals. For high frequency applications where an antenna's length is to be minimised, another choice is the helical antenna. In addition, mobile terminal manufacturers encounter a constant demand for smaller and smaller terminals. This demand for miniaturisation is combined with desire for additional functionality such as having the ability to use the terminal at different frequency bands and different cellular systems.

[0005] It is commercially desirable to offer portable terminals which are capable of operating in widely different frequency bands, e.g., bands located in the 800 MHz, 900 MHz, 1500 MHz, 1800 MHz, 1900 MHz, 2.0 GHz and 2.45 GHz regions. Accordingly, antennas which provide adequate gain and bandwidth in a plurality of these frequency bands will need to be employed in portable terminals. Several attempts have been made to create such antennas. In order to reduce the size of the portable radio terminals, built-in antennas have been implemented over the last couple of years. The general desire today is to have an antenna, which is not visible to the customer. Today different kinds of patches are used, with or without parasitic elements. The most common built-in antennas currently in use in mobile phones include are the so called planar inverted-F antennas (PIFA). This name has been adopted due to the fact that the antenna looks like the letter F tilted 90 degrees in profile. Such an antenna needs a feeding point as well as a ground connection. If one or several para-

sitic elements are included nearby, they can be either grounded or dielectrically separated from ground.

[0006] The trend for future mobile terminals is a continued reduction of size and weight, and built in type miniature antennas are strongly desired for portable mobile terminals within 300 MHz-3000 MHz frequency range for this reason. Existing built in type antennas used in mobile phones includes microstrip antennas and the aforementioned PIFA. Microstrip antennas are low profile, small in size and light in weight. The PIFA has already been used in mobile phone handsets and is one of the most promising designs, as suggested by K.Qassim, "Inverted-F antenna for portable handsets ", IEE Colloquium on Microwave Filters and Antennas for Personal Communication Systems, pp.3/1-3/6, Feb.1994, London, UK. However, as the mobile phone becomes smaller and smaller, both conventional microstrip patch and PIFA antennas are still too large to fit the small phone chassis. This is particularly problematic when the new generations of phones needs multiple antennas for cellular, wireless local area network, GPS and diversity.

[0007] Lai, Kin, Yue, Albert et al has published a meandering inverted-F antenna in WO 96/27219., by which it is possible to reduce the antenna size to about 40% of conventional PIFA antennas. In many applications, multi-band performance is needed. In order to make multi-band built-in antenna, Ying has proposed a printed twin-spiral dual band antenna in US patent No 6,166,694. The disclosure includes a dual-band built-in antenna having two strip-line parts which resonant at different frequencies. In that design, the bandwidth of antenna is smaller because thin strip lines are used as radiators. A compensation method is therefore also proposed, i.e. a resistor loading is introduced on the matching bridge, which gives wider bandwidth at the loss of some gain.

[0008] WO 00/36700 discloses a further improved dual band patch antenna, proposed by Ying. That antenna use the same concept as the printed twin spiral antenna which was stated in US 6,166,694, the antenna havinh two parts which operate in two frequency ranges. Instead of using narrow strip, it uses the patches with slot cutting, the slotted patches are used as radiators, they can offer wider bandwidth.

[0009] For triple band application, the upper band need the band from 1710 MHz to 1990 MHz. The solution in WO 00/36700 can not meet the requirement. A semi built-in multi-band printed patch antenna was proposed by Ying in WO 01/17063. That design needs larger surface area to realise triple band antenna.

In WO 01/91233 Ying has proposed a compact multi-band branch printed antenna. The antenna can cover tri-band by using a parasitic metal element.

[0010] In order to be able to have double-band performance in two telecommunication systems having different frequency bands, it must be possible to operate at four different bands. An example thereof is the GSM application, which in USA and in Europe covers four

bands: GSM800 (824MHz-894MHz) in America, GSM900 (880-960MHz) in Europe, GSM1800 (1710-1880MHz) in Europe and GSM1900 (1850-1990MHz) in America. Consequently, there is a general need four communication terminals, and antennas therefor, capable of quad-band operation.

Summary of the invention

- 10 **[0011]** Hence, it is an object of the present invention to overcome the deficiencies related to the prior art. More specifically, it is an object to provide an antenna for radio communication which is capable of operating in different dual-band radio communication systems, where the dual-band frequencies are different in such different communication systems.
- 15 **[0012]** According to a first aspect, this object is fulfilled by a tuneable radio antenna device for a radio communication terminal, said antenna device comprising a ground substrate, an antenna element, and a ground pole connecting the antenna element to the ground substrate, wherein an impedance switch device is operable to change the impedance of a connection between the antenna element and the ground substrate fortuning the antenna element to different resonance frequencies.
- 20 **[0013]** In one embodiment the impedance switch device comprises a MEMS switch.
- 25 **[0014]** Preferably said antenna element comprises a first elongated member, and a second elongated member which is shorter than said first member, wherein said impedance switch is operable to switch between a first impedance setting, in which said members are resonant for a first lower and a first higher frequency band, respectively, and a second impedance setting, in which said members are resonant for a second lower and a second higher frequency band, respectively, different from said first lower and a first higher frequency band.
- 30 **[0015]** In one embodiment said impedance switch device comprises a first switch operable to change the impedance of a first connection between the first member and the ground substrate, and a second switch operable to change the impedance of a second connection between the second member and the ground substrate. Said first switch is preferably devised to optionally set,
- 35 **[0016]** for said first connection, a first impedance in said first impedance setting or a second impedance in said second impedance setting, and said second switch is correspondingly devised to optionally set, for said second connection, a third impedance in said first impedance setting or a fourth impedance in said second impedance setting .
- 40 **[0017]** In one embodiment said antenna element is a branched antenna, wherein said first member is a first branch of the antenna element, and said second member is a second branch of said antenna element, each branch having a first and a second end, wherein said branches are connected to said ground pole at their first ends. Said first switch is preferably devised to connect

the second end of said first branch to ground, through said first or second impedance, and said second switch is preferably devised to connect the second end of said second branch to ground, through said third or fourth impedance. Preferably, said impedance switch device comprises a single pole double throw micro electromechanical systems switch. Said antenna device is, in a specific embodiment, a low-profile planar inverted-F antenna.

[0017] In another embodiment from the branched antenna type, said first member of the antenna element is a main radiating element, the first connection forming said ground pole, and said second member is a parasitic element to said antenna element, connectable to ground at one of its ends by said second connection. Said first switch is preferably devised to connect said ground pole to ground, through said first or second impedance, and said second switch is preferably devised to connect said second connection said parasitic element to ground, through said third or fourth impedance. Preferably, said impedance switch device comprises a double pole double throw micro electromechanical systems switch. In a specific embodiment, said antenna device is a low-profile planar parasitic inverted-F antenna.

[0018] According to a second aspect, the object of the invention is fulfilled by a communication terminal devised for multi-band radio communication, comprising a housing, a user input and output interface, wherein that communication terminal comprises an antenna device according to the aforementioned first aspect of the invention, and optionally any of the further features of the mentioned embodiments.

[0019] According to a third aspect, the object of the invention is fulfilled by a tuneable quad-band radio antenna device for a radio communication terminal, said antenna device comprising a ground substrate, a dual-band antenna element comprising a first elongated antenna member, a second elongated antenna member, which is shorter than said first member, a ground connection connecting said members to ground, and an impedance switch device operable to change the impedance of said connection for tuning the antenna element, such that in a first impedance setting the antenna element is resonant to a first and a second radio frequency, and in a second impedance setting the antenna element is resonant to a third and a fourth radio frequency which are frequency shifted from said first and second radio frequencies.

[0020] According to a fourth aspect, the object of the invention is fulfilled by a communication terminal devised for quad-band radio communication, comprising a housing, a user input and output interface, wherein that communication terminal comprises an antenna device according to the aforementioned third aspect.

Brief description of the drawings

[0021] The features and advantages of the present in-

vention will be more apparent from the following description of the preferred embodiments with reference to the accompanying drawings, on which

- 5 Fig. 1 schematically illustrates a tuneable multi-band radio antenna device according to a first embodiment of the invention;
- 10 Fig. 2 schematically illustrates the feeding and the ground connections of one branch of the embodiment according to Fig. 1;
- 15 Fig. 3 schematically illustrates the impedance switch arrangement at the ground connections of the different branches according to the embodiment of Fig. 1;
- 20 Fig. 4 schematically illustrates a tuneable multi-band radio antenna device according to a second embodiment of the invention;
- 25 Fig. 5 schematically illustrates the feeding and the ground connection of the main radiating element of the embodiment according to Fig. 2;
- 30 Fig. 6 schematically illustrates the impedance switch arrangement at the ground connections of the main radiating element and the parasitic according to the embodiment of Fig. 4;
- 35 Fig. 7 schematically illustrates an exemplary communication terminal implementing an antenna design according to an embodiment of the invention;
- 40 Fig. 8 illustrates a simulation result of the return loss for a specific embodiment in accordance with Fig. 1; and
- 45 Fig. 9 illustrates a simulation result of the return loss for a specific embodiment in accordance with Fig. 4.

Detailed description of preferred embodiments

- 5 **[0022]** The present description refers to radio terminals as a device in which to implement a radio antenna design according to the present invention. The term radio terminal includes all mobile equipment devised for radio communication with a radio station, which radio station also may be mobile terminal or e.g. a stationary base station. Consequently, the term radio terminal includes mobile telephones, pagers, communicators, electronic organisers, smartphones, PDA:s (Personal Digital Assistants), vehicle-mounted radio communication devices, or the like, as well as portable laptop computers devised for wireless communication in e.g. a WLAN (Wireless Local Area Network). Furthermore, since the antenna as such is suitable for but not restricted to mobile use, the term radio terminal should also be understood as to include any stationary device arranged for radio communication, such as e.g. desktop computers, printers, fax machines and so on, devised to operate with radio communication with each other or some other radio station. Hence, although the structure and characteristics of the antenna design according to the invention is mainly described herein, by way of example, in the implementation in a mobile phone, this is not to

be interpreted as excluding the implementation of the inventive antenna design in other types of radio terminals, such as those listed above. Furthermore, it should be emphasised that the term comprising or comprises, when used in this description and in the appended claims to indicate included features, elements or steps, is in no way to be interpreted as excluding the presence of other features elements or steps than those expressly stated.

[0023] The present invention is described herein with reference mainly to two exemplary embodiments, both relating to cellular mobile phones. Both examples relates to planar inverted F antennas for built-in use. However, from the instant description a person skilled in the art will realise that, although not shown, the invention as claimed is equally applicable to other types of antennas for radio communication purposes, such as e.g. stub antennas or micro-strips.

[0024] Figure 1 discloses schematically a first embodiment of the invention. With the evolution of micro-electronics and memory storage capability, the communication terminal providers do their best to meet the general requirements of the terminal usage for having smaller and smaller terminals. In order to obtain a compact size terminal, miniature multi-band antennas are strongly recommended. The embodiment of figure 1 discloses a PIFA devised according to the invention. This kind of antenna has a feeding pin 5 and a ground pole 6, contacting the antenna to the ground plane to of the printed circuit board PCB 2. The specific embodiment of figure 1 is a dual-band branched antenna, having a first elongated member 3 resonant to a first radio frequency, and a second elongated member 4, which is shorter than the first member 3. The second member 4 is resonant to a second radio frequency, higher than the first radio frequency. Without reference to the specific size and form of the antenna, this is a well-known design for a dual-band radio antenna. If the desire is to use the antenna device 1 for four-band application, this kind of antenna cannot be directly used. Four-band application is desirable to make the radio terminal adapted to different dual-band systems having different pairs of resonant frequencies. One example of were a four-band coverage would be desirable, is for a terminal capable of dual band application in the GSM systems of both Europe and the USA. This is the example for which the embodiment of figure 1, as well as the embodiment of figure 4 disclosed further down, will be described, although a person skilled in the art would realise that the invention as disclosed will have a technical effect also in other cases were a four-band application is desirable.

[0025] The geometry of the antenna device 1 disclosed in figure 1 is a branch PIFA antenna. The long branch 3 operates at GSM 900, whereas the short branch 4 operates at GSM 1800, which means that the antenna is tuned to Europe mode. Ground pole 6 connects the first member 3 to ground at a first end 7, from which member 3 extends in an elongated shape to a

second end 9. Similarly, member 4 extends from a first end 8 at the ground connection of the ground pole 6 to a second end 10. At the second end 9 of member 3 a connection 11 is arranged between the member 3 and

5 ground 2 through a reactance loading 21. Member 4 has a separate connection 12 connecting the second end 10 of the member to ground 2 through another reactance loading 22. Each reactance loading 21, 22 has an adaptive impedance which contributes to the resonance 10 frequency of the respective branch. In accordance with the invention, each reactance loading comprises an impedance switch 21, 22 capable of shifting the impedance through the connections 11, 12. The impedance switches 21, 22 are in one embodiment operated separately, 15 but are in a preferred embodiment operated as one impedance switch device 20, indicated in the drawing by the dashed line.

[0026] Figure 2 illustrates the principle for the frequency tuning by impedance shifting for the first branch 20 member 3. The reactance loading of the impedance switch 21 is optionally set to a first impedance value Z1 or a second impedance value Z2. When the switch 21 is set to Z1 the resonance frequency for antenna member 3 is adapted to a resonance of 900 MHz to cover 25 Europe mode. When the switch 21 is shifted such that connection 11 connects antenna member 3 to ground 2 through the second impedance Z2, the resonance frequency is decreased such that it covers 800 MHz for the American mode.

30 **[0027]** Figure 3 corresponds to figure 2, but illustrates the impedance switches 21, 22 for both branches 3, 4. Similar to the first impedance switch 21, also described in figure 2, figure 3 illustrates that the impedance switch 22 for branch 4 comprises a third impedance Z3 and a forth impedance Z4, through either of which connection 12 may connect antenna member 4 to ground 2. Antenna member 4 is preferably, as mentioned earlier, the branch adapted for the higher frequency in a dual-band system. When switch 22 connects ground 2 to Z3, the resonance frequency of antenna member 4 will be set 35 to 1800 MHz to cover Europe mode. By switching connection 12 such that antenna member 4 connects to ground 2 through impedance Z4, the resonance frequency of branch 4 is switched to 1900 MHz to cover 40 the American mode. In a preferred realisation of this embodiment, a SPDT (single pole double throw) MEMS (micro electro-mechanical systems) switch is used in the impedance switches 21, 22. The use of a MEMS switch for this purpose is advantageous since it has low 45 insertion loss and low power consumption. Furthermore, since the MEMS switch is mechanical it does not consume any power when it is not used, since no current passes through it, which makes it ideal for mobile phone application. SPDT switches are otherwise known in the 50 art for the purpose of switching between receive or transmit, as disclosed for instance by Schultz et al. in US 4,803,447. In one embodiment, the switch is not only controlled by the MEMS, but rather comprised therein.

By applying different levels of voltage to the MEMS, different impedances are thereby obtained through the switch.

[0028] A computer simulation has been made on an antenna principle according to the antenna device 1 of figure 1. Figure 8 shows a diagram of the return loss, as obtained through the simulation measurements. When the impedance switch device 20 is in its first setting, such that switch 21 provides an impedance Z1 for connection 11 and switch 22 provides an impedance Z3 for connection 12, the antenna device 1 is adapted to Europe mode. The simulation result relating to that setting is indicated by numeral 81 and figure 8. When the impedance switch device 20 is shifted, such that switch 21 provides impedance Z2 for connection 11 and switch 22 provides impedance Z4 for connection 12, the antenna device 1 is adapted to American mode. The simulation results for American mode are indicated by numeral 80 in figure 8. As is evident from the drawing, the dual-band coverage is suitable shifted by the impedance switch device 20, wherein a quad-band antenna device 1 has been obtained. The simulation for which the results are disclosed in Fig. 8 are performed on the antenna alone. When the antenna is enclosed in a housing or chassis of a communication terminal, such as a cellular phone of Fig. 7, both curves 80 and 81 will be slightly shifted downwards in frequency. Thereby the resonances of the antenna elements will be suitably located at 800 and 1900 MHz or 900 and 1800 MHz, respectively, for America or Europe mode.

[0029] Figure 4 illustrates another embodiment of the present invention. In this case, the antenna device 101 comprises a first elongated antenna member 30, connected to ground 20 through a ground pole 60, and fed through a connection 50. The first antenna member 30 extends in an elongated manner from a first end 70 at the ground connection 60 to a second end 90, and the length of member 30 is selected such that it is resonant to a first radio frequency. In a manner well-known to a skilled person a second antenna member 40 is implemented in the form of a parasitic element, connected to ground at a connection 120 at a first end 80 of the parasitic element. The parasitic 40 extends from the first end 80 in an elongated manner to a second end 100, and the length of the parasitic 40 is shorter than the length of the first antenna member 30, such as the parasitic 40 is resonant to a second and higher radio frequency. This geometry corresponds to a dual-band parasitic antenna, which as such is known in the prior art. In this embodiment, the ground connection 60, or ground pole 60, connects the antenna element 30 to ground 20 through an impedance switch 210. Similarly, the ground connection 120 of the parasitic 40 is connected to ground 20 through second impedance switch 220. The switches 210,220 may be operated separately, although in one embodiment they are commonly operated in an impedance switch device 200, indicated in the drawing by the dashed line.

[0030] Figure 5 discloses the basic principal of the impedance switch 210 on the first antenna member 30. The impedance switch 210 is optionally set such that the ground connection 60 connects the antenna member 30 to ground 20 through a first impedance Z10, or such that the connection 60 connects antenna member 30 to ground 20 through a second impedance Z20. By changing the impedance of the ground connection 60 the resonance frequency of the antenna element 30 is

5 affected such that it will be resonant for different radio frequency dependent of the impedance setting.
[0031] Figure 6 illustrates, in a manner similar to figure 3, the arrangement of the impedance switch device 200 for the embodiments disclosed in figure 4. In figure 15 6, both antenna elements 30 and 40 are showed, and ground connections 60,120 through the respective impedance switches 210,220 to ground 20. As for the first impedance switch 210, the second impedance switch 220 is optionally set to a third impedance Z30 for ground 20 connection 120, or to a forth impedance Z40 for the ground connection 120 between antenna element 40 and ground 20. By switching the impedance switch 220, the resonance frequency for the parasitic element 40 will be shifted. In a specific realisation of this embodiment, 25 a DPDT (double pole double throw) MEMS switch is used to control both switches 210,220. Also the DPTD has low insertion loss and low power consumption, and is therefore advantageous to use for this purpose. Furthermore, since the MEMS switch is mechanical it does 30 not consume any power when it is not used, as recited above. Also in this case, the switch may be comprised in the MEMS.

[0032] Figure 9 illustrates simulation results corresponding to those for figure 8, but now for an embodiment as disclosed in figures 4-6. It should be noted that 35 the grading of the horizontal axis is the same as for Fig. 8, i.e. from 0.5 to 2.5 GHz in steps of 0.1 GHz. In Europe mode the GSM system operates at 900 and 1800 MHz, and reference numeral 91 indicates the return loss when 40 the antenna device 101 is tuned to Europe mode by having the impedance switch device 200 set to impedance Z10 and Z30, respectively. When switching the impedance switch device 200 to impedances Z20 and Z40, respectively, the antenna device 101 is tuned to the 45 American mode, wherein the lower frequency is shifted downwards and the higher frequency is shifted upwards to yield the return loss as disclosed by the curve indicated through numeral 90. When the antenna is enclosed in a housing or chassis of a communication terminal, 50 such as a cellular phone of Fig. 7, both curves 90 and 91 will be slightly shifted downwards in frequency. Thereby the resonances of the antenna elements will be suitably located at 800 and 1900 MHz or 900 and 1800 MHz, respectively, for America or Europe mode.

[0033] Consequently, the present invention provides 55 a solution for adapting a dual-band radio antenna into a quad-band radio antenna, by using an impedance switch on the ground connection of the antenna to tune

the resonance frequencies. As a person skilled in the art will realise, the antenna may have more than two branches. Furthermore, each impedance switch may have more than two selectable settings, e.g. three or four different impedances, for tuning to different frequencies. The embodiments disclosed are selected primarily to provide a simplified yet enabling disclosure of the elected ways of implementing the invention. A suitable field of application is, as previously mentioned, for portable mobile phones in cellular radio communication systems, such as GSM, D-AMPS, UMTS, CDMA2000 etc.

[0034] Fig. 7 illustrates a communication radio terminal in the embodiment of a cellular mobile phone 300 devised for multi-band radio communication. The terminal 300 comprises a chassis or housing 350, carrying a user audio input in the form of a microphone 310 and a user audio output in the form of a loudspeaker 320 or a connector to an ear piece (not shown). A set of keys, buttons or the like constitutes a data input interface 330 usable e.g. for dialling, according to the established art. A data output interface comprising a display 340 is further included, devised to display communication information, address list etc in a manner well known to the skilled person. The radio communication terminal 300 includes radio transmission and reception electronics (not shown), and is devised with an antenna, such as a built-in antenna device 1 inside the housing 350, which antenna device is indicated in the drawing by the dashed line as an essentially flat object. According to the invention, this antenna device 1, e.g. corresponding to Fig. 1 or Fig. 4, includes a flat ground substrate 2 or 20, an antenna element 3,4 or 30,40 with a radio signal feeding point 5 or 50, a ground pole 6 or 60, and an impedance switch 20 or 200, connecting the antenna element to ground through a selectable impedance in order to tune the antenna to different bands. The other features of the antenna design according to the present invention described above are naturally equally valid for the radio terminal implemented embodiment of Fig. 7.

[0035] The foregoing has described the principles, preferred embodiments and modes of operation of the present invention. However, the invention should not be construed as being limited to the particular embodiments discussed above. For example, while the antenna of the present invention has been discussed primarily as being a radiator, one skilled in the art will appreciate that the antenna of the present invention would also be used as a sensor for receiving information at specific frequencies. Similarly, the dimensions of the various elements may vary based on the specific application. Furthermore, the impedances of the invention may be capacitive, resistive and/or inductive, highly dependent on the specific design of the antenna elements and the desired resonances. Thus, the above-described embodiments should be regarded as illustrative rather than restrictive, and it should be appreciated that variations may be made in those embodiments by those skilled in

the art without departing from the scope of the present invention as defined by the following claims.

5 Claims

1. A tuneable radio antenna device (1) for a radio communication terminal, said antenna device comprising a ground substrate (2), an antenna element (3,4), and a ground pole (6) connecting the antenna element to the ground substrate, **characterised in that** an impedance switch device (20) is operable to change the impedance of a connection (11,12) between the antenna element and the ground substrate for tuning the antenna element to different resonance frequencies.
2. The tuneable radio antenna device as recited in claim 1, **characterised in that** said impedance switch device comprises a MEMS switch.
3. The tuneable radio antenna device as recited in claim 1 or 2, **characterised in that** said antenna element comprises a first elongated member (3), and a second (4) elongated member which is shorter than said first member, wherein said impedance switch is operable to switch between a first impedance setting (Z1,Z3), in which said members are resonant for a first lower and a first higher frequency band, respectively, and a second impedance setting (Z2,Z4), in which said members are resonant for a second lower and a second higher frequency band, respectively, different from said first lower and a first higher frequency band.
4. The tuneable radio antenna device as recited in claim 3, **characterised in that** said impedance switch device comprises a first switch (21) operable to change the impedance of a first connection (11) between the first member and the ground substrate, and a second switch (22) operable to change the impedance of a second connection (12) between the second member and the ground substrate.
5. The tuneable radio antenna device as recited in claim 4, **characterised in that** said first switch is devised to optionally set, for said first connection, a first (Z1) impedance in said first impedance setting or a second (Z2) impedance in said second impedance setting, and in **that** said second switch is devised to optionally set, for said second connection, a third (Z3) impedance in said first impedance setting or a fourth (Z4) impedance in said second impedance setting .
6. The tuneable radio antenna device as recited in any of the preceding claims, **characterised in that** said first member is a first branch (3) of the antenna el-

ement, and said second member is a second branch (4) of said antenna element, each branch having a first (7,8) and a second (9,10) end, wherein said branches are connected to said ground pole (6) at their first ends.

7. The tuneable radio antenna device as recited in claim 6, **characterised in that** said first switch (21) is devised to connect the second end (9) of said first branch to ground, through said first (Z1) or second (Z2) impedance, and said second switch (22) is devised to connect the second end (10) of said second branch to ground, through said third (Z3) or fourth (Z4) impedance.

8. The tuneable radio antenna device as recited in claim 6 or 7, **characterised in that** said impedance switch device comprises a single pole double throw micro electromechanical systems switch.

9. The tuneable radio antenna device as recited in any of the previous claims, **characterised in that** said antenna device is a low-profile planar inverted-F antenna.

10. The tuneable radio antenna device as recited in any of the claims 1 - 5, **characterised in that** said first member is a main radiating element (30) of the antenna element, the first connection (60) forming said ground pole, and wherein said second member is a parasitic element (40) to said antenna element, connectable to ground at one (80) of its ends by said second connection (90).

11. The tuneable radio antenna device as recited in claim 10, **characterised in that** said first switch (210) is devised to connect said ground pole (60) to ground, through said first (Z10) or second (Z20) impedance, and said second switch (220) is devised to connect said second connection (90) said parasitic element to ground, through said third (Z30) or fourth (Z40) impedance.

12. The tuneable radio antenna device as recited in claim 10 or 11, **characterised in that** said impedance switch device comprises a double pole double throw micro electromechanical systems switch.

13. The tuneable radio antenna device as recited in any of the claims 10 - 12, **characterised in that** said antenna device is a low-profile planar parasitic inverted-F antenna.

14. A communication terminal (300) devised for multi-band radio communication, comprising a housing (350), a user input (310,330) and output (320,340) interface, **characterised in that** communication terminal

comprises an antenna device (1) according to any of the previous claims.

- 5 15. A tuneable quad-band radio antenna device (1) for a radio communication terminal, said antenna device comprising a ground substrate (2), a dual-band antenna element comprising a first elongated antenna member (3), a second (4) elongated antenna member, which is shorter than said first member, and a ground connection (11,12) connecting said members to ground, **characterised in that** an impedance switch device (20) is operable to change the impedance of said connection (11,12) for tuning the antenna element, such that in a first impedance setting (Z1,Z3) the antenna element is resonant to a first and a second radio frequency, and in a second impedance setting (Z2,Z4) the antenna element is resonant to a third and a fourth radio frequency which are frequency shifted from said first and second radio frequencies.

- 20 16. The tuneable radio antenna device as recited in claim 15, **characterised in that** said impedance switch device comprises a MEMS switch.

- 25 17. A communication terminal (300) devised for quad-band radio communication, comprising a housing (350), a user input (310,330) and output (320,340) interface, **characterised in that** communication terminal comprises an antenna device (1) according to claim 15.

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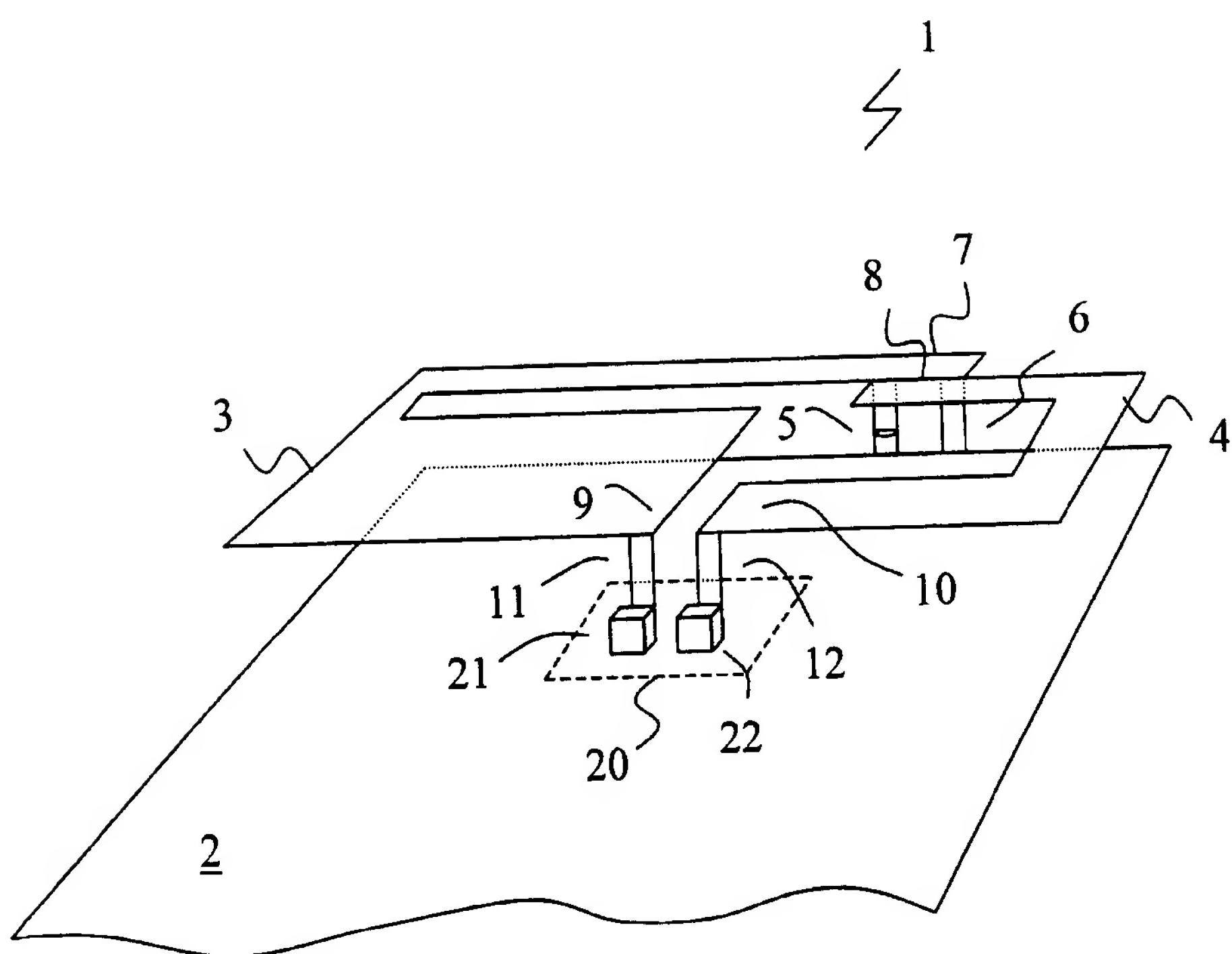


Fig. 1

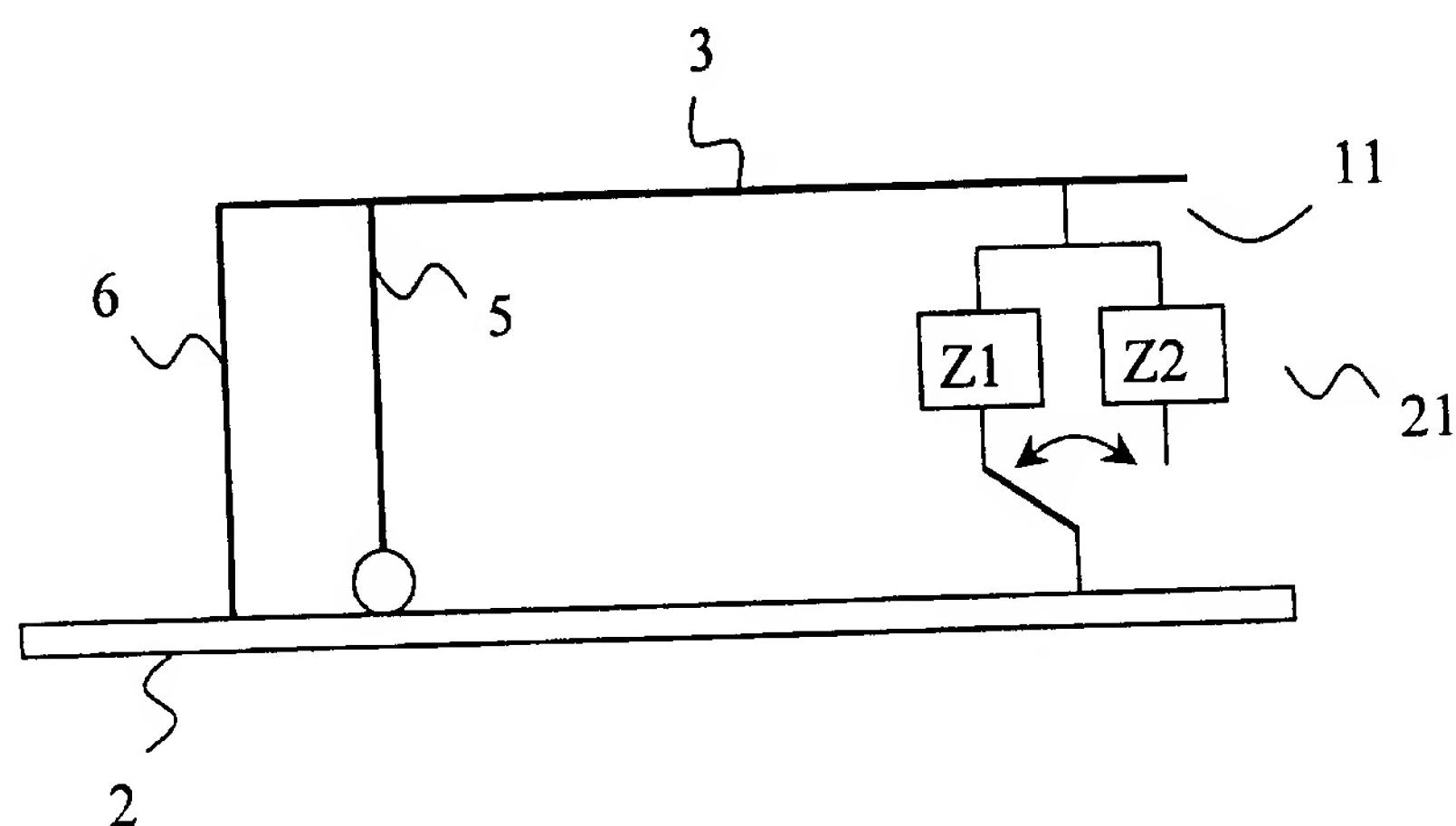


Fig. 2

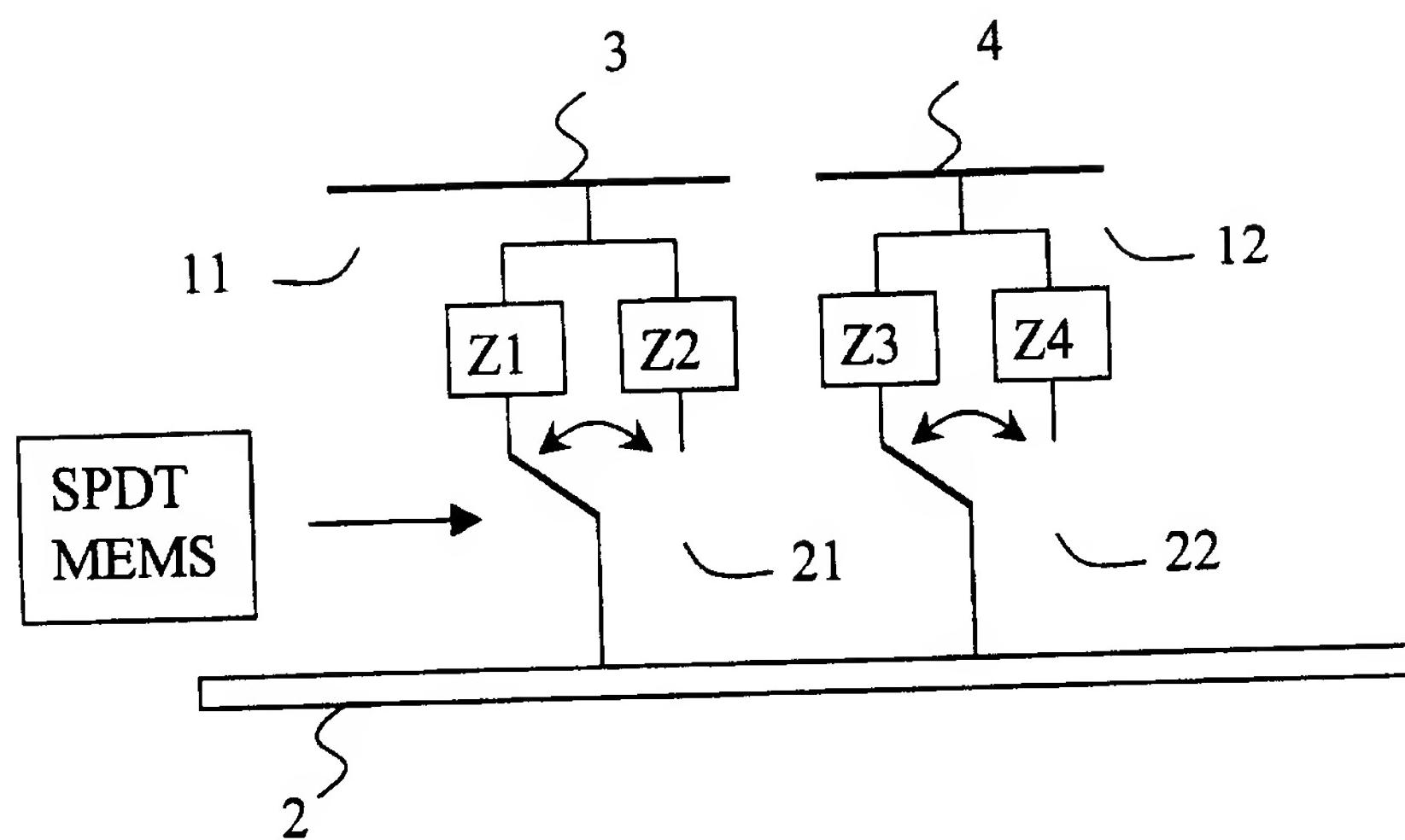


Fig. 3

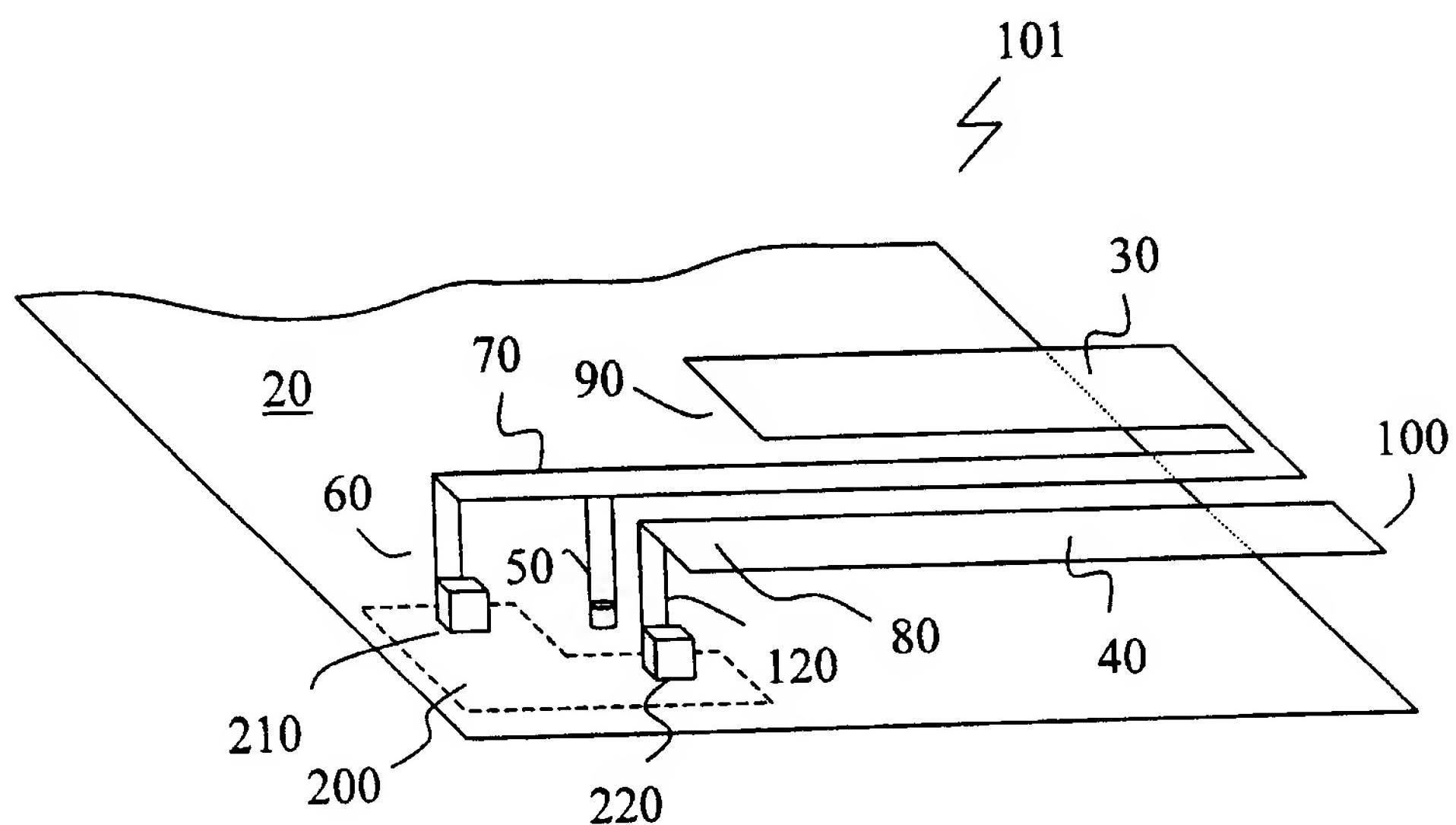


Fig. 4

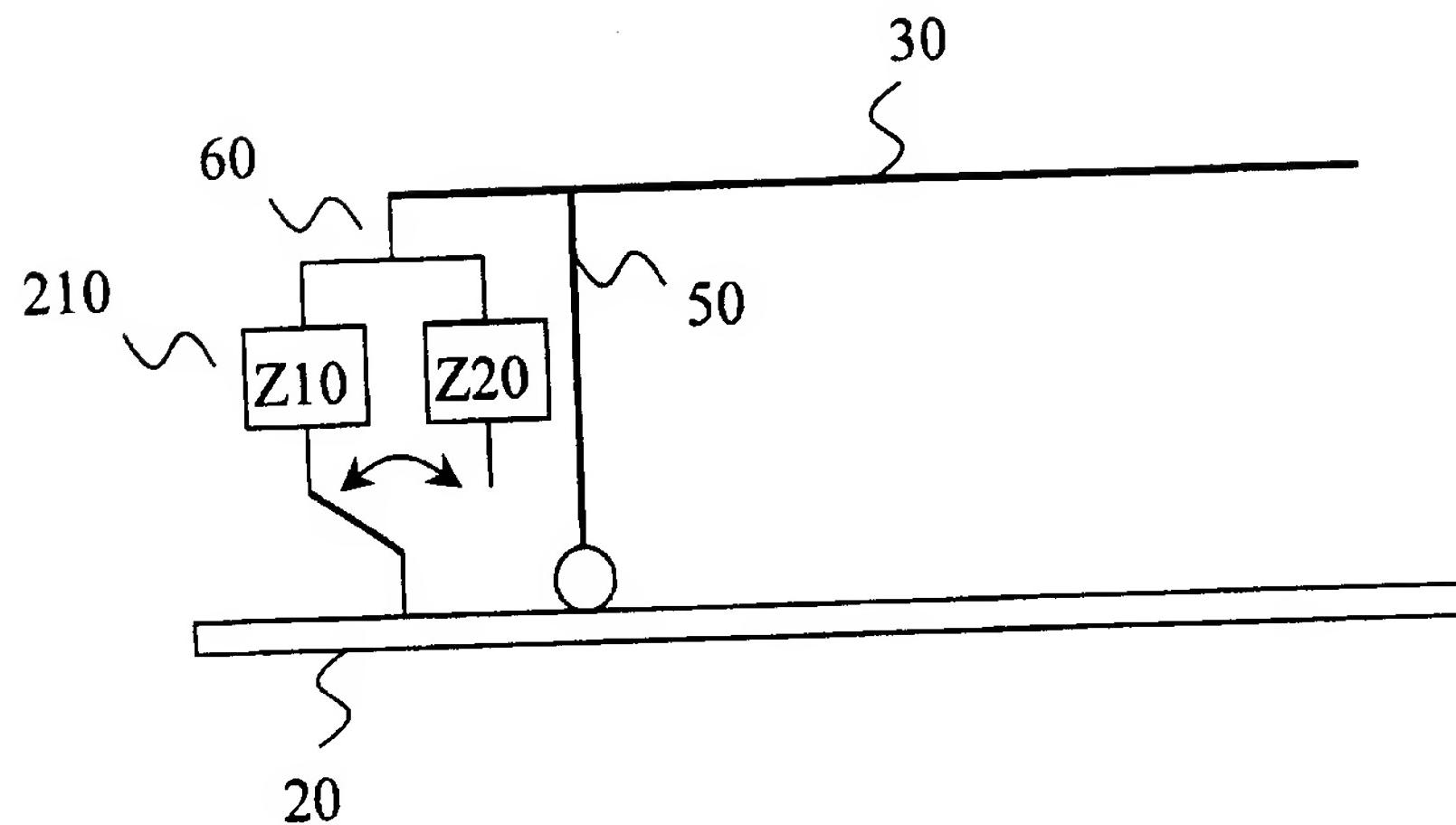


Fig. 5

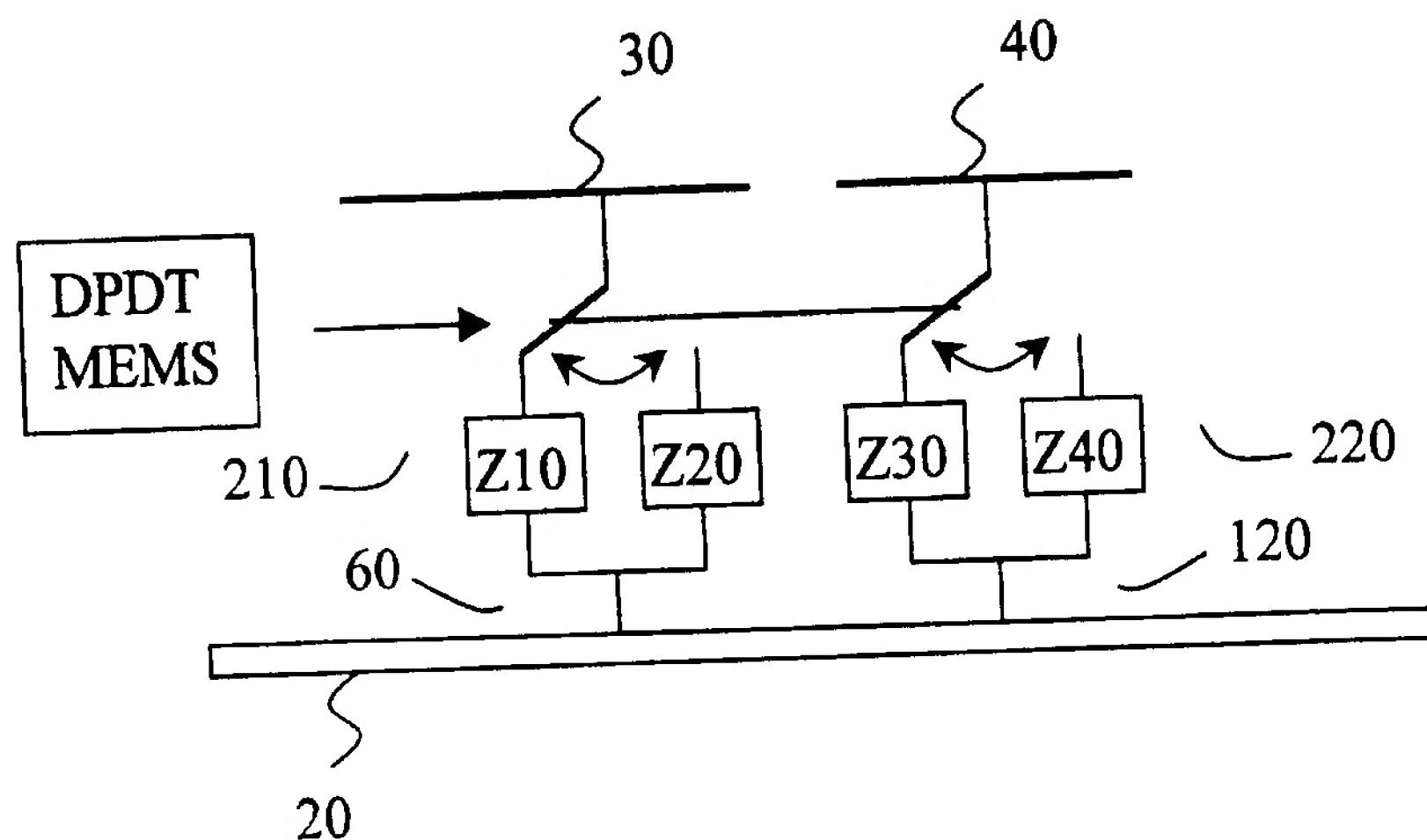


Fig. 6

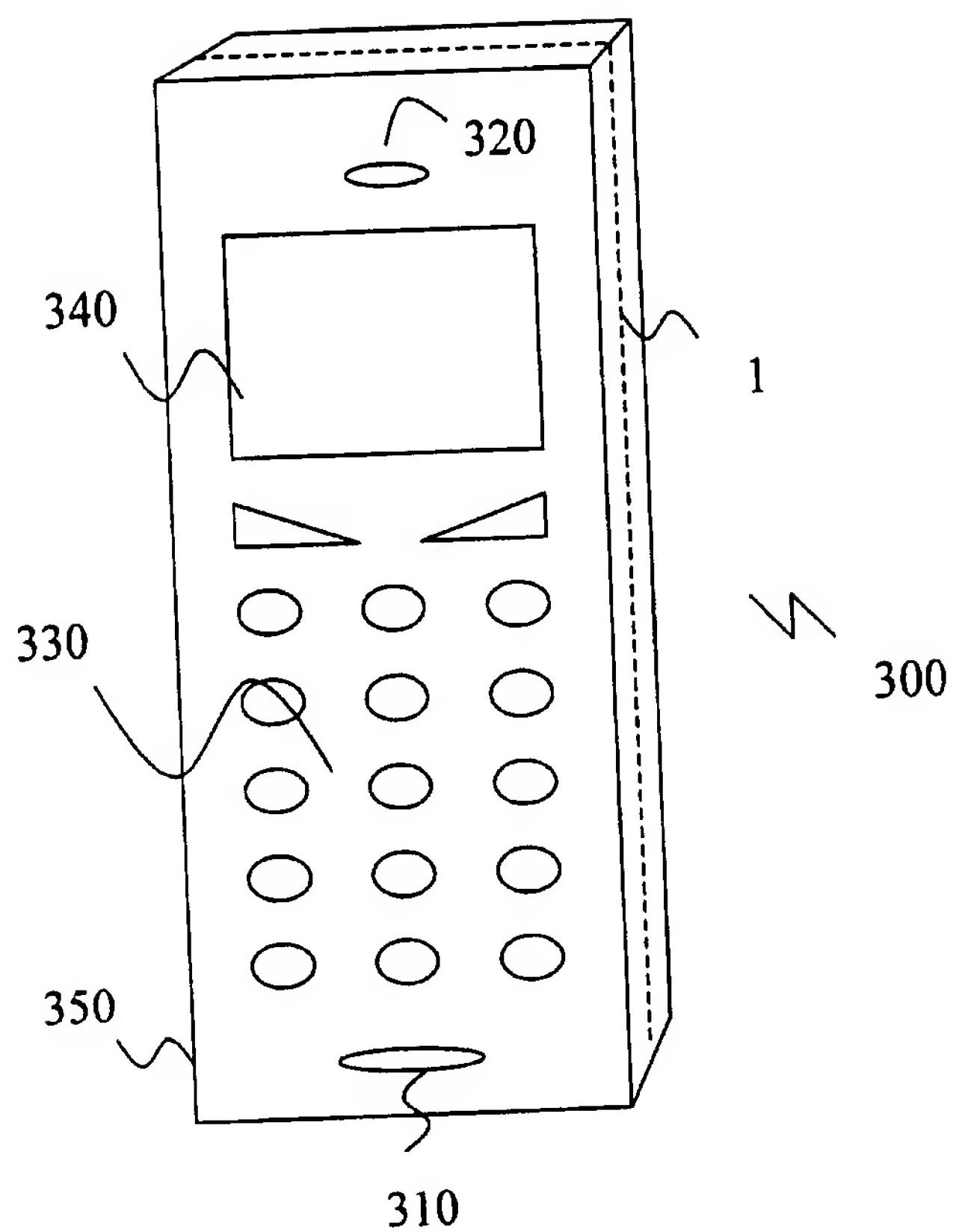


Fig. 7

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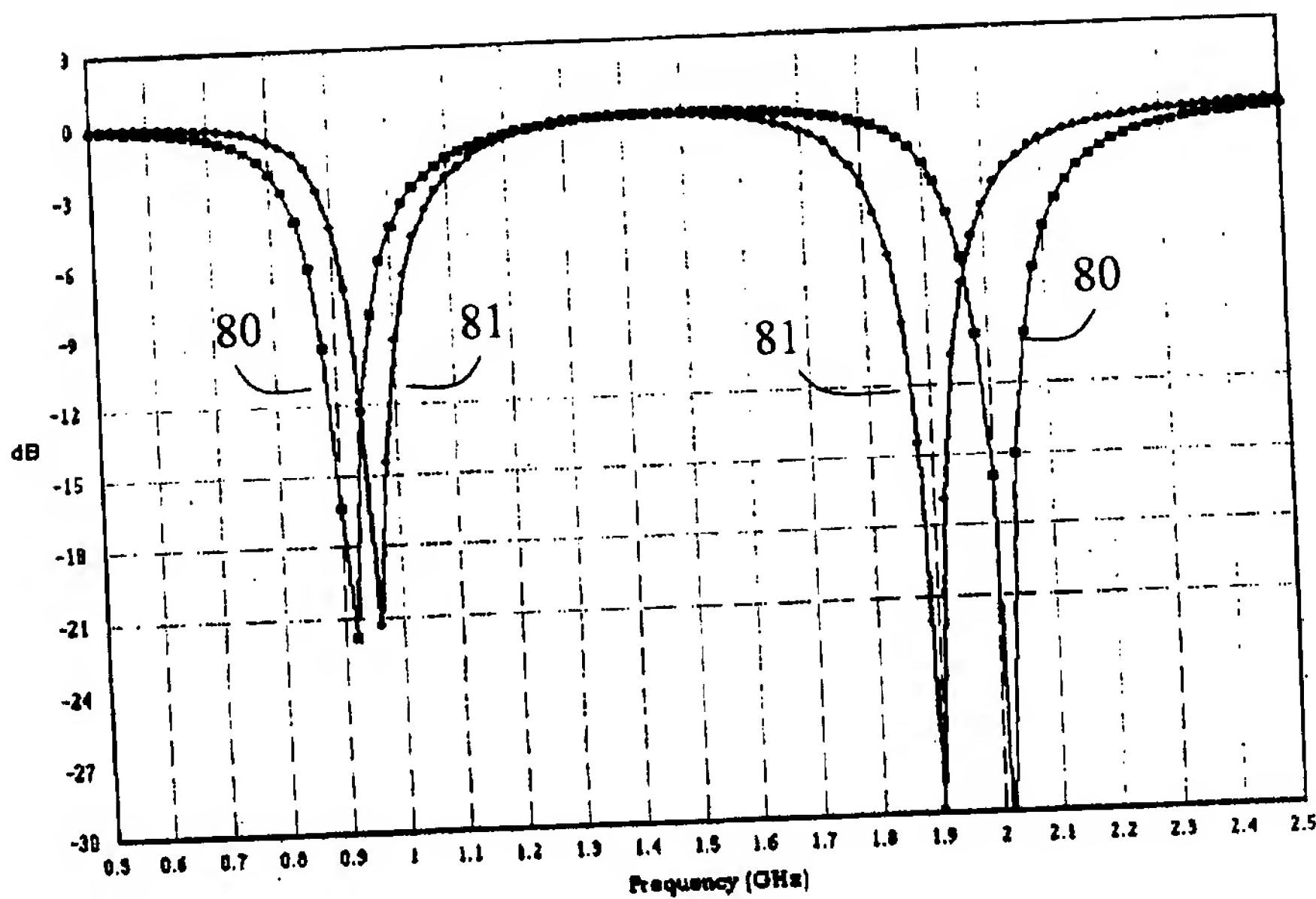


Fig. 8

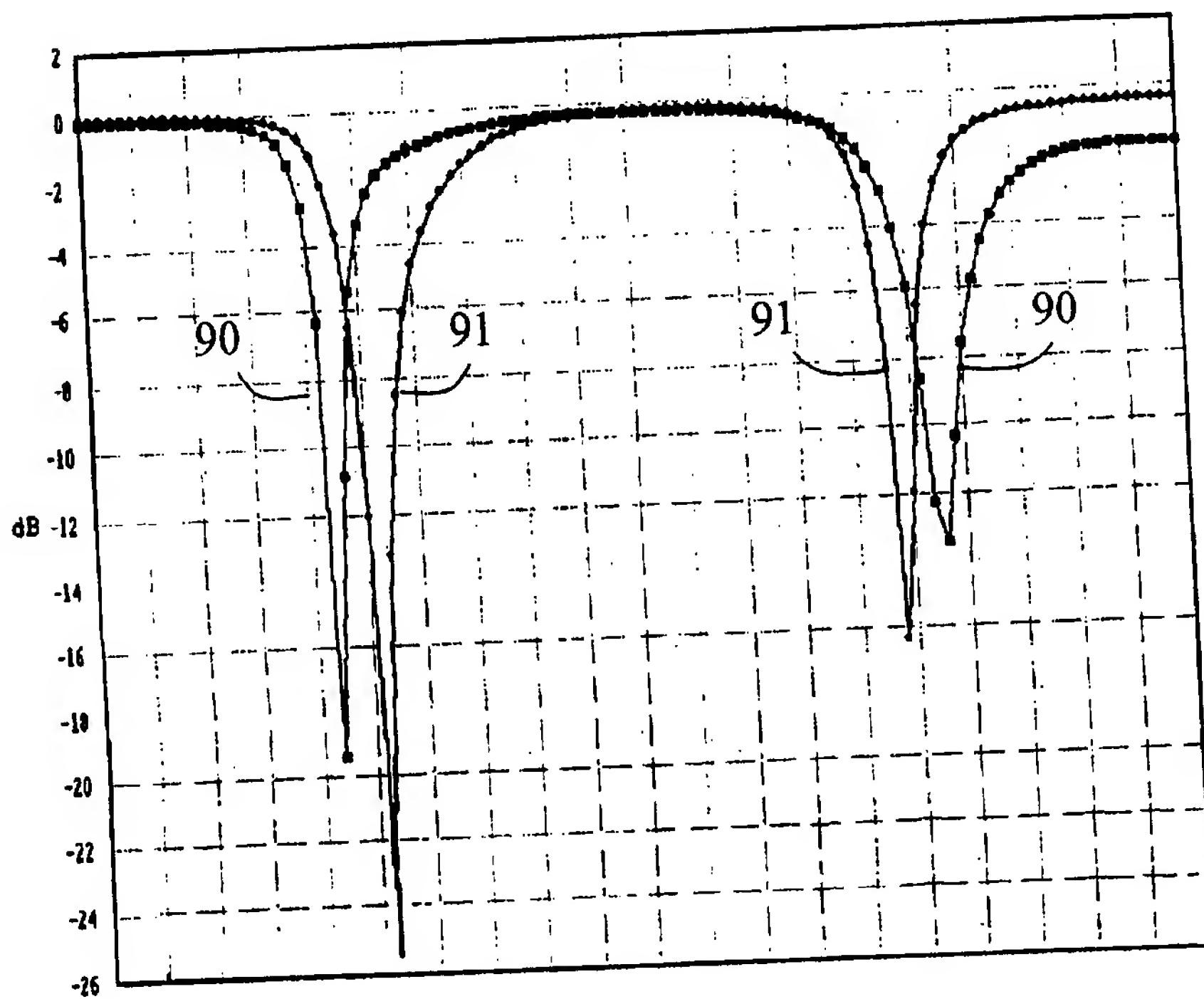


Fig. 9



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Office

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T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document															

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